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Research Article

Effect of application compost and vermicompost from market waste on soil chemical properties and plant growth

Syarifinnur[1*], Yulia Nuraini[2], Budi Prasetya[2]

[1] Postgraduate Program, Faculty of Agriculture, Brawijaya University, Jl. Veteran No. 1 Malang 65145, Indonesia
[2] Soil Science Department, Faculty of Agriculture Brawijaya University, Jl. Veteran No. 1 Malang 65145, Indonesia

[*]corresponding author: syarifinnur@gmail.com

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Abstract

This study was conducted to determine the effect of compost and vermicompost from market organic waste on the soil chemical properties and the growth of maize. The treatments tested were three doses of compost (2.5, 5, and 10 t/ha), three doses of vermicompost (2.5, 5, and 10 t/ha), and one control (without compost or vermicompost). At the time of harvest (10 weeks after planting), maize shoot dry weight, root dry weight, cob length, cob diameter, cob with husk, and cob dry weight, as well as the soil chemical properties organic carbon (C), total nitrogen (N), total phosphorus (P), available P, total potassium (K), and pH were observed. Maize plant height, leaf number, and stem diameter were observed at 2, 4, 6, and 8 weeks after planting. The results showed that the application of compost and vermicompost significantly affected soil chemical properties and the yield of maize. The application of 10 t vermicompost/ha resulted in the highest yield of maize and highest increase of soil organic carbon, total phosphorus available phosphorus, total potassium, and pH by 7.21%, 112.41%, 287.44%, 85.44% and 17.58%, respectively. The application of 10 t compost/ha resulted in the highest increase of soil total N by 44%.

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Introduction

Inceptisol is a type of soil found in West Nusa Tenggara, with an area of nearly 1,505,000 ha or about 86.57% of the land area (Hikmatullah and Suharta, 1999). One of the problems of Inceptisol for agriculture is low soil fertility to support plant growth. Low soil fertility is characterized by low organic matter content, unstable soil aggregates, sensitivity to erosion, and low primary nutrients (N, P, K) content (Ghosh et al., 2018). Several studies have shown the characteristics of soil chemical properties in several places, including very low and low criteria (Baharuddin et al., 2016; Mulyati et al., 2017). Sukartono et al. (2017) reported that the Inceptisols of West Nusa Tenggara had a very low fertility rate that was indicated by the organic C content of 0.18% and total N of 0.09%. The low level of soil fertility in dry land has also been reported by Arifin et al. (2017), where the organic C content is low (1.07%), and total N is very low (0.09%).

In intensive farming systems, fertilizers, pesticides, superior seeds, and high-efficiency machines are generally used to increase agricultural yields. One of the efforts made by farmers in West Nusa Tenggara to increase agricultural yields is to use inorganic fertilizers, and only a few farmers use organic fertilizers. The unbalanced use of inorganic fertilizers has caused soil damage and environmental pollution, which has led to a decrease in land quality (Chakraborty et al., 2011; Ding et al., 2016)

Improving soil fertility can be done by adding organic matter such as green manure, compost, manure, or fresh organic matter. The use of organic materials is also an alternative to reduce dependence on inorganic fertilizers. Besides that, using organic materials is one solution to reduce environmental pollution and obtain safe agricultural products. Some organic materials to improve soil properties have not been carried out optimally. Due to the low productivity of dry land, the availability of conventional organic matter (plant residues) is also limited, and they still have to compete with livestock (Efendi, 2016).

In sustainable agriculture, the application of organic matter to the soil is one way to improve soil quality (Koul et al., 2021). Soil organic matter has a vital role and function in soil improvement, including physical, biological, and chemical properties (Ngo et al., 2012; Kučerík et al., 2018; Herlambang et al., 2020; Winarso et al., 2020). Improvements in soil properties will certainly affect soil fertility, affecting plant growth and production. Soil organic matter is very important to maintain soil structure stability, good drainage, increase water holding capacity, and increase soil nutrient availability (Calleja et al., 2015; Curtin et al., 2016). Proper management of soil organic matter needs to be a serious concern so that there is no degradation of organic matter. An alternative source of soil organic matter to overcome fertility problems in the agricultural land of West Nusa Tenggara is market organic waste (fruit and vegetable waste).

The market organic waste has never been used as a source of organic matter to improve soil fertility in the dry land of West Nusa Tenggara because it is generally disposed of immediately. Market organic waste is one solution that can be used because the amount is abundant and always increases from time to time. It becomes an alternative to add soil organic matter and increase nutrient content and soil biological activity. The use of market organic waste in fresh form (fresh waste) directly to the land is difficult because of the smell and large volume. One technique that can be used to overcome these problems (smell and volume) is to process the market organic waste into compost and vermicompost;.

Compost and vermicompost are organic fertilizers that can improve soil conditions, improve macronutrient retention and plant growth in degraded tropical soils (Jouquet et al., 2011). The use of these two organic materials shows an increase in line with public awareness of the importance of getting healthy food (González et al., 2010; Fornes et al., 2012). Many studies show that the application of compost to the soil can increase nutrient content and plant growth. Compost is a type of organic fertilizer produced by the decomposing plant and animal tissues assisted by living organisms to meet plant nutrient needs. Compost significantly affects the physical, chemical, and biological soil properties (Villegas and Cedillo, 2018). Vermicompost is the result of the decomposition of organic matter using earthworms. Types of earthworms that can be used include *Eisenia feotida*, *Perionyx excavates*, *Pheretima hupiensis*, *Eudrillus* sp., and *Lumbricus* sp. (Anwar, 2009). According to Quintern et al. (2016), the use of vermicompost in agricultural activities has various advantages, including the content of more available nutrients, increasing the presence of soil microbes, increasing the ability of the soil to hold water, as well as improving plant growth and increasing crop yields like compost. Research related to compost and vermicompost has been carried out on annual plants and other types of plants. The results show that these two organic materials positively affect soil and plant growth (Huang et al., 2014; Ravindran et al., 2016). In West Nusa Tenggara, no study has been conducted to test organic fertilizers from market organic waste using composting and vermicomposting methods.

This study, therefore, aimed at elucidating the effect of compost and vermicompost derived from market organic wastes on the chemical properties of an Inceptisol and maize growth.

Materials and Methods

A pot experiment was conducted in a screen house at Telaga Waru Village, Labuapi District, West Lombok, East Nusa Tenggara Province, from August to December 2019. Organic matters used for this study were compost and vermicompost made from market organic waste obtained from Mandalika central market of Mataram City. The process of making compost and vermicompost was the same. The difference was the presence of earthworms. Compost was prepared without earthworms, and vermicompost was prepared with earthworms. The organic waste used consisted of cabbage, banana peduncle, and pineapple wastes. The compost and vermicompost were prepared following the combination methods of Garg et al. (2011) and Yadav et al. (2016).

The market organic wastes were first chopped to approximately 5 cm to make them uniform and palatable by earthworms. The chopped organic wastes were then mixed with a ratio of 3:1:1. The cow dung was diluted with 1 L of water prior to mixing with market organic wastes. The cow dung and rice straw were obtained from live-stocked farms and rice fields at Ampenan, Mataram, West Nusa Tenggara. The mixture of chopped organic wastes, cow dung, and rice straw was placed in a plastic tray and covered with a sack and incubated for seven days. After incubation of seven days, the mixture was inoculated with 200 earthworms belonging to *Eudrillus eugeniae* (for vermicomposting) and without earthworm (for composting). The moisture content was maintained 50-60% by sprinkling water periodically. The materials were mixed and turned the organic matter heap manually every 2-4 days for 40 days. At the final composting and vermicomposting stage, the yielded compost and vermicompost were subjected to carbon (C), nitrogen (N), phosphorus (P), potassium (K), and pH analyses following the methods developed by BALITAN (2009) (Table 1). The treatments tested were one control (without additional compost or vermicompost), three doses of compost (2.5, 5, and 10 t/ha), and three doses of vermicompost (2.5, 5, and 10 t/ha). Each treatment was mixed with 8 kg of oven-dried soil that passed through a 2 mm sieve and placed in a plastic pot. The soil used in this study was collected from Telaga Waru Village, West Lombok, West Nusa Tenggara ($8^0$37'33" S, $116^0$07'00" E), with Inceptisols soil order. The soil used has a loam texture with low soil fertility. Characteristics of the soil used for this study are shown in Table 2.

Table 1: Characteristics of compost and vermicompost used in the study.

Parameter	Organic Fertilizer		Criteria Based on Kepmentan No. 261*
	Compost	Vermicompost	
N (%)	1.95	1.77	Minimum 2% ($N + P_2O_5 + K_2O$)
P (%)	0.29	0.43	Minimum 2% ($N + P_2O_5 + K_2O$)
K (%)	1.04	0.77	Minimum 2% ($N + P_2O_5 + K_2O$)
pH	7.60	7.30	4-9
Organic C (%)	25.69	19.38	Minimum 15%
C/N	13.17	11.00	≤15

*Decree of the Minister of Agriculture of the Republic of Indonesia No: 261/KPTS/SR.310/M/4/2019.

Table 2. Characteristics of soil used for the study.

Soil Parameters	Value	Criteria*
Organic C (%)	1.17	Low
Total N (%)	0.15	Low
C/N ratio	7.9	Low
Total P (mg/100g)	23.74	Low
Available P (ppm)	2.03	Very low
Total K (mg/100g)	19.67	Low
CEC (mg/100g)	15.45	Low
pH (H_2O)	5.68	Acid
Exchangeable Cation		
Ca (mg/100g)	5.83	Low
Mg (mg/100g)	1.82	Moderate
K (mg/100g)	1.14	Low
Na (mg/100g)	0.63	Moderate
Base saturation (%)	58.03	Moderate
Texture		
Sand (%)	42	
Slit (%)	44	Loam
Clay (%)	14	

Source: BALITAN (2009)

The mixture of compost or vermicompost and soil in the pot was incubated for seven days. The seven treatments were arranged in a completely randomized design with three replications. After incubation of 7 days, each pot received basal NPK fertilizers (15:15:15) with a rate equivalent to 100 kg/ha. Three maize seeds of Jambore Variety were planted in each pot and thinned to one plant after one week, leaving one plant with the best growth. Water was supplied daily to each pot to 80% field capacity conditions. After 35 days, the second application of NPK fertilizer was made to each treatment with a dose of 100 kg/ha. At 2, 4, 6, and 8 weeks after planting, observations were made on plant height, stem diameter, and the number of leaves of the maize plant. At the harvest time (10 weeks after planting), shoot dry weights, root dry weight, cob diameter, cob length, cob with husk, and dry weight, and the soil characteristic were observed. The plant material was oven-dried at 60 ^{0}C for 48 h. The soil chemical properties measured were the contents of organic C, total N, total P, available P, total K, and pH following the methods developed by BALITAN (2009). The data obtained were subjected to analysis of variance at the 95% confidence level (α=5%), followed by the Duncan Multiple Range Test (DMRT) at 5%. All statistical analyses were carried out using the SPSS 24.

Results and Discussion

Changes in soil chemical characteristic

The application of compost and vermicompost significantly affected the chemical characteristics of the soil studied (Table 3). The application of 10 t vermicompost/ha increased the soil organic C content significantly compared to other treatments. The application of 10 t vermicompost/ha increased the soil organic C content by 7.21% compared to the initial content of soil organic C. However, the increase of the organic C was not significantly different from that of the application of compost 2.5, 5, and 10 t compost/ha; and 2.5 and 5 t vermicompost/ha. The increase of organic C content is due to the decomposition of vermicompost that accelerates microorganism activity to release CO_2 and other important reactions that require the assistance of soil microorganisms (Pathma and Sakthivel, 2012). According to Ghosh et al. (2021), vermicompost could increase carbon content and soil structural stability better than other treatments (Xiang et al., 2018).

The application of compost and vermicompost significantly affected the total soil N content. The highest soil total N content was observed in the 10 t compost/ha treatment, which was not significantly different from the 10 t vermicompost/ha treatment, but significantly different from other treatments. Compared with the control, the soil total N increased by 44.44 %. The ability of compost to enhance the total N was due to the dose of compost given and compost characteristics (Goswami et al., 2017).

Table 3. Effect of application of compost and vermicompost on soil chemical characteristics.

Treatment	Soil Chemical Characteristics					
	Organic C (%)	Total N (%)	Total P (mg/100 g)	Available P (ppm)	Total K (mg/100g)	pH
Control	1.11 a	0.09 a	13.54 a	2.07 a	14.42 a	5.52 a
Compost 2.5 t/ha	1.13 ab	0.10 ab	17.81 b	3.01 b	17.58 b	5.67 a
Compost 5 t/ha	1.13 b	0.12 ab	21.48 c	3.30 b	20.03 cd	5.84 ab
Compost 10 t/ha	1.14 b	0.14 d	25.61 d	4.60 c	24.14 e	6.16 bc
Vermicompost 2.5 t/ha	1.14 b	0.10 ab	20.63 c	3.60 b	18.55 bc	5.88 ab
Vermicompost 5 t/ha	1.14 b	0.12 bc	25.13 d	4.93 c	21.36 d	5.89 ab
Vermicompost 10 t/ha	1.19 c	0.13 d	28.76 e	8.02 d	26.74 f	6.49 c

Note: Numbers followed by the same letter in the same column are not significantly different at α 5% DMRT. C = carbon, P = phosphorus, K = potassium

Compost and vermicompost application significantly increased the soil total P and available P with the increasing rate of compost and vermicompost applied. The application of 10 t vermicompost/ha increased soil total P and available P by 112.41% and 287.44%, respectively. Research conducted by Asrin et al. (2019) reported that the application of vermicompost had increased the value of the available P content of the soil by 15.45 ppm, which was greater than the application compost by 13.82 ppm. Uz and Tavali (2014) also reported that the application of 10 t vermicompost/ha increased the presence of soil P from 38 ppm to 81 ppm. The application of compost and vermicompost significantly increased total K along with the dose of compost and vermicompost applied. The application of 10 t vermicompost/ha produced the highest total K (26.74 mg/100g) or increased by 85.44% compared to the control treatment with the lowest total K (14.42 mg/100g).

The application of compost and vermicompost increased soil pH along with the increase of the dose of compost and vermicompost applied. The highest pH increase was obtained in the 10 t vermicompost/ha treatment that was not significantly different from the 10 t compost/ha treatment, but it was significantly different from other treatments. Compared to the control treatment, the application of 10 t vermicompost/ha increased the pH by 17.57%. According to Yagi and Ferreira (2003), the increased soil pH is due to the decomposition process of organic matter producing various organic compounds such as humic and phosphoric acids, which can reduce the concentration of H^+ and increase OH^- ions.

Growth of maize

The application of compost and vermicompost significantly affected the plant height, stem diameter, and the number of leaves (Table 4). At the age of 8 weeks after planting, the control treatment produced the lowest maize growth; in contrast, the 10 t vermicompost/ha treatment produced the highest plant growth. This is related to the increased availability of P in the soil due to the application of vermicompost. Syarifinnur et al. (2020) reported that the application of 10 t vermicompost/ha increased the soil availability from 2.60 ppm to 13.69 ppm (465.34%). The high response of maize to the application of vermicompost indicates the important role of nutrients in the vermicompost in the growth of maize (Scaglia et al., 2016). Several studies have shown that the application of vermicompost has a positive effect on the productivity and quality of crops such as strawberries (Zuo et al., 2018), tomato (Ravindran et al., 2019), carrot (Chatterjee et al., 2014), and lettuce (Ali et al., 2007).

Yield components of maize

The application of compost and vermicompost significantly affected shoot and root dry weight (Table 5). The highest shoot and root dry weights were observed in the 10 t vermicompost/ha treatment, which increased by 43.47% and 91.88%, respectively, compared to the control treatment. However, the shoot and root dry weights obtained from the 2.5 t compost/ha treatment were not significantly different from those obtained from the 5 t compost/ha treatment, although they were significantly different from those of the 10 t compost/ha treatment and all vermicompost treatments. Piya et al. (2018) revealed that vermicompost enhances plant growth and yield and the nutritional value of crops produced. Length and diameter of cob obtained in 10 t vermicompost/ha treatment increased by 41.25% and 35.91% compared to control treatment. However, these values were not significantly different from other treatments.

Table 4. Effect of the application of compost and vermicompost on maize plant growth.

Treatments	Observation time			
	2 WAP	4 WAP	6 WAP	8 WAP
		Plant height (cm)		
Control	11.67 a	37.70 a	76.57 a	130.00 a
Compost 2.5 t/ha	13.47 a	39.37 a	82.30 b	148.67 b
Compos 5 t/ha	15.30 a	46.37 bc	86.33 b	153.67 b
Compos 10 t/ha	21.10 a	49.87 c	88.47 b	157.00 bc
Vermicompost 2.5 t/ha	15.77 a	41.13 ab	86.40 b	155.00 b
Vermicompost 5 t/ha	16.00 b	49.03 c	91.67 c	168.00 c
Vermicompost 10 t/ha	24.70 b	57.43 d	97.60 c	177.33 d
		Stem diameter (mm)		
Control	2.93 a	8.77 a	18.87 a	25.37 a
Compost 2.5 t/ha	3.00 a	10.37 ab	20.40 b	25.60 bc
Compost 5 t/ha	3.20 a	11.47 bc	21.13 bc	26.37 bc
Compost 10 t/ha	3.77 a	12.37 c	22.00 c	27.50 bc
Vermicompost 2.5 t/ha	3.13 a	11.17 bc	21.87 bc	26.43 bc
Vermicompost 5 t/ha	3.27 b	11.70 bc	22.13 c	27.03 bc
Vermicompost 10 t/ha	3.93 b	16.27 d	24.27 d	29.07 d
		Number of leaves (sheet/plant)		
Control	4.33 a	7.33 a	9.33 a	10.67 a
Compost 2.5 t/ha	5.00 b	8.00 ab	10.33 ab	12.33 b
Compost 5 t/ha	5.00 b	8.67 cb	11.67 c	13.33 bc
Compost 10 t/ha	5.00 b	9.33 c	11.67 c	13.67 c
Vermicompost 2.5 t/ha	5.00 b	8.67 bc	10.67 c	13.33 bc
Vermicompost 5 t/ha	5.00 b	9.00 c	11.67 c	14.33 c
Vermicompost 10 t/ha	5.33 b	10.33 d	13.33 d	16.00 d

Note: WAP = week after planting. Numbers followed by the same letter in the same column are not significantly different at α 5% DM RT.

Table 5. Effect of application compost and vermicompost on yield of maize growth.

Treatments	Shoot dry weight (g)	Root dry weight (g)	Cob length (cm)	Cob diameter (cm)	Cob with husk (g)	Cob dry weight (g)
Control	90.76 a	9.85 a	15.50 a	33.53 a	104.00 a	16.00 a
Compost 2.5 t/ha	98.90 b	12.79 b	17.47 b	37.17 b	180.67 b	49.00 b
Compost 5 t/ha	101.50 bc	14.35 b	17.93 bc	39.47 bc	213.67 c	51.33 b
Compost 10 t/ha	109.28 c	16.37 c	18.23 bc	41.40 bc	249.67 e	57.33 c
Vermicompost 2.5 t/ha	107.74 c	13.73 c	18.00 bc	40.33 c	233.00 d	52.67 b
Vermicompost 5 t/ha	118.27 d	16.46 c	19.07 c	40.60 c	255.00 ef	61.67 cd
Vermicompost 10 t/ha	130.21 e	18.90 d	21.40 d	45.57 d	268.33 f	62.67 d

Note: Numbers followed by the same letter in the same column are not significantly different at α 5% DMRT.

The application of compost and vermicompost significantly increased cob with husk and cob dry weights. The cob with husk and cob dry weights increased along with the increase in the dose of compost and vermicompost applied. The lowest cob with husk and cob dry weights were observed in the control treatment. The highest cob with husk and cob dry weights were obtained in the 10 t vermicompost/ha treatment, which was not significantly different from the 5 t vermicompost/ha treatment. However, it was significantly different from other treatments, except 10 t compost/ha. Compared with the control treatment, the cob with husk and cob dry weights of the 10 t vermicompost/ha treatment increased by 158.01% dan 291.69%.

Relationships between soil available P, shoot dry weight, and cob dry weight

The relationships between compost application (Figure 1) and soil available P, shoot and cob dry weight were in linear line $y = 7.26x + 76.56$ and $y = 15.33x - 6.32$, with the R^2 values of 0.99 and 0.74, respectively. This equation shows a positive trend; the soil available P content will increase the shoot and cob dry weight. There were strong relationships between soil available P on the vermicompost treatments with shoot and cob dry weight in the linear line y = 6.38x + 82.06 and y = 6.82x + 16.50, where x is soil available P, and the R^2 values are 0.93 and 0.62, respectively (Figure 2). These values show positive trends of vermicompost application. The increase in soil available P will increase shoot dry and cob dry weight. The high organic matter content can improve the quality of soil chemical properties by increasing the soil biological activity and producing nutrients for plant growth. This relationship shows a positive trend, the higher soil available P content, will increase the plant growth and yield. Research conducted by Ichriani et al. (2018) and Purnomo et al. (2021) showed that an increase in soil available P would increase plant growth and yields.

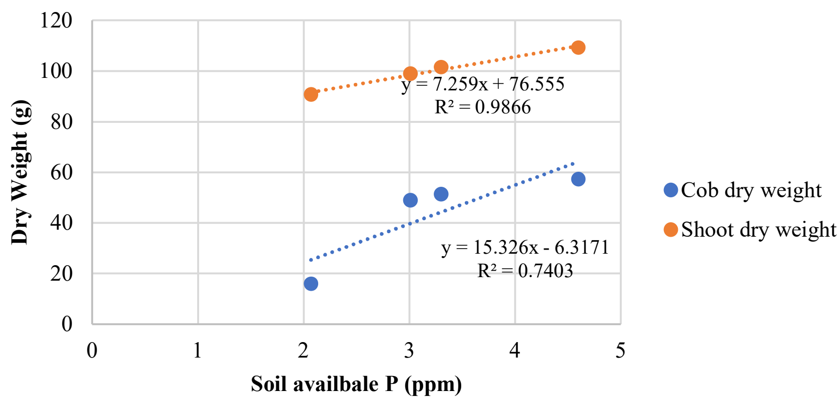

Figure 1. Relationships between soil available P (ppm), shoot dry weight (g), and cob dry weight (g) on compost treatments.

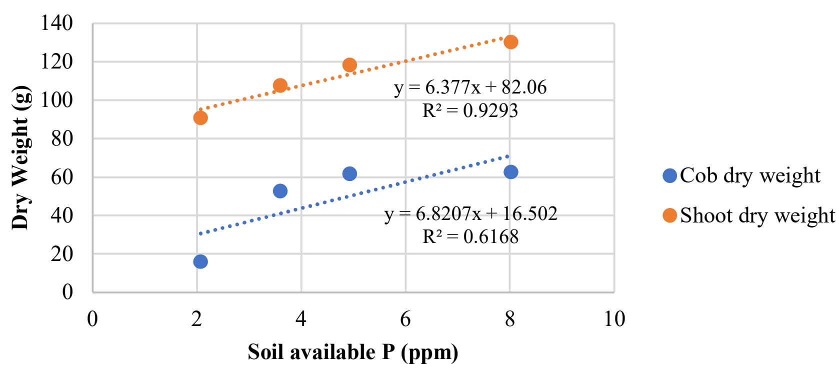

Figure 2. Relationship between soil available P (ppm), shoot dry weight (g), and cob dry weight (g) on vermicompost treatments.

Conclusion

The application of compost and vermicompost from the market organic market significantly improved soil chemical properties, growth, and yield of maize. The application 10 t compost/ha resulted in the highest increase of total N by 44%, and the application of 10 t vermicompost/ha resulted in the highest increase of organic C, total P, total K, and pH, by 7.21%, 112.41%, 85.44%, 17.58%, respectively, compared to control. The application of 10 t vermicompost/ha could improve soil fertility and plant growth in an Inceptisol of West Nusa Tenggara.

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